Check for updates

https://doi.org/10.4047/jap.2023.15.5.238

# Influences of luting cement shade on the color of various translucent monolithic zirconia and lithium disilicate ceramics for veneer restorations

Ghada Alrabeah[1]*, Nawaf Alamro[2], Atif Alghamdi[2], Ahmed Almslam[2], Meshari Azaaqi[2]
[1]Department of Prosthetic Dental Sciences, College of Dentistry, King Saud University, Riyadh, Saudi Arabia
[2]Intern, College of Dentistry, King Saud University, Riyadh, Saudi Arabia

**ORCID**
Ghada Alrabeah
https://orcid.org/0009-0001-6450-9725
Nawaf Alamro
https://orcid.org/0000-0001-8567-9574
Atif Alghamdi
https://orcid.org/0009-0003-9888-4384
Ahmed Almslam
https://orcid.org/0009-0001-2935-094X
Meshari Azaaqi
https://orcid.org/0009-0002-5376-9596

**PURPOSE.** The purpose of this study was to assess the effect of resin cement shade on the color of different novel ultratranslucent monolithic zirconia and lithium disilicate veneer materials. **MATERIALS AND METHODS.** For a total of 40 specimens, flat cylindrical discs with a 9-mm diameter and 0.5-mm thickness were created using CAD/CAM technology. The specimens were divided into five groups according to their material (n = 8) (e.max, Prettau, Aidite, Shofu and Dima) using A1 shade. Resin discs with the same diameter and shade as the specimens served as tooth-colored substructures. Three shades (neutral, light and warm) of resin cement try-in pastes (Variolink Esthetic LC) were used as the luting cement material. The color of each material group was measured before and after cementation using the three cement shades, and the CIE L*a*b* coordinates were obtained with a spectrophotometer. Values for the translucency parameter (TP) and color change delta E (E) before (baseline) and after cementation of each specimen were determined. To compare differences among the material groups within each shade of cement and among various shades of cement within each material, the data were analyzed using one-way ANOVA and post hoc testing. **RESULTS.** Color coordinates L*, a* and b* significantly changed after the application of try-in pastes relative to baseline values, with a noticeable decrease in lightness (L*) ($P < .05$). A significant color change ($\Delta E$) was observed in all tested materials after cementation, with $\Delta E$ values exceeding 3.3 ($P < .05$). Although TP changed after cementation for most materials tested, these changes were not statistically significant ($P > .05$). Shofu and Dima ceramics showed the lowest TP values, while Aidite and Prettau showed the highest TP values. For e.max, translucency decreased after cementation with neutral and warm shades, and it significantly increased after cementation with a light shade. **CONCLUSION.** The shade of cement significantly altered the final color of the ceramic veneer material to a level above the threshold at which the clinical perception of color change occurred (> 3.3). The TP was not influenced by the cement shade. The translucency levels of the novel ultratranslucent multilayer monolithic zirconia ceramics Aidite and Prettau were higher than that of the lithium disilicate e.max material. [J Adv Prosthodont 2023;15:238-47]

**KEYWORDS**
Optical properties; Dental ceramics; Color change; Translucency; Zirconia; Resin cement shade

**Corresponding author**
Ghada Alrabeah
Department of Prosthetic Dental Sciences, College of Dentistry, King Saud University, Riyadh 11545, Saudi Arabia
**Tel** +966114677325
**E-mail** galrabeah@ksu.edu.sa

**Received** June 16, 2023 /
**Last Revision** October 11, 2023 /
**Accepted** October 25, 2023

## INTRODUCTION

To date, dental ceramic veneers have become a popular treatment modality for heavily discolored teeth, misaligned teeth and diastema closure occurring mainly in anterior teeth.[1] Such restorations provide superior esthetic results with minimally invasive procedures. The increased demand has encouraged many companies to produce new materials that can provide high esthetic tooth-colored restorations combined with superior strength properties to ensure long-term durability with a minimal thickness of 0.3 - 0.5 mm. The recent introduction of ultratranslucent zirconium oxide ceramic materials has served to merge strength with improved tooth color matching.[2] However, the color match of esthetic restorative materials and teeth remains a challenge, as the optical properties of teeth are greater than the color itself.[3] Several optical properties influence the appearance of restorations to resemble natural teeth, including translucency.[4] The translucency is the amount of light passing through a material. This optical property is highly dependent on the veneer material itself and on the optical properties of the veneer substructure.[1,5] Veneers gain retention from the underlying resin cement layer that bonds them to the tooth structure. Resin cements are supplied in different shades to mask the color of the underlying tooth structure and to further aid in color matching to the adjacent natural tooth.[6-11] Therefore, the cement shade may influence the color of the overlying ceramic veneer. In fact, by using an opaque cement shade, Comba *et al*. stated that the opacity of ceramic materials tested (Katana Zirconia and Lithium Disilicate) was influenced by the cement shade and material type; but translucency was only affected by the ceramic type and not by the shade of the cement.[10] Conversely, Bayindir *et al*. confirmed changes in the translucency of the monolithic zirconia material tested after cementation with an opaque shade of cement.[11] Although research on the influence of cement shade on the final color of all ceramic restorations has been performed, no general clinical guidelines have been established to govern the usage of available cement shades in clinical scenarios. In addition, conflicting findings in previous studies necessitate further investigations to understand the exact interactions between certain materials and certain cements. With the continuous introduction of novel highly translucent monolithic zirconia materials into the market, additional investigation is necessary to comprehend the full range of optical properties of these new zirconia varieties and to investigate the various factors that may affect the final color of such restorations, which can affect the aesthetic outcome of the procedure. This research is particularly important since an increasing number of novel generations of ultratranslucent multilayer monolithic zirconia ceramics have translucency values that are greater than those of commonly used lithium disilicate ceramics.

Therefore, the aim of the present study is to investigate the effects of three shades of cement on the color and translucency of different novel ultratranslucent multilayer monolithic zirconia veneers recently launched in the market relative to the widely used lithium disilicate ceramic veneers.

## MATERIALS AND METHODS

To ensure that all specimens were uniform, 40 flat cylindrical ceramic disks with a 9-mm diameter and 0.5-mm thickness were created using CAD/CAM technology. According to the specimen material, five groupings were created (n = 8). One group was lithium disilicate ceramic material (e.max), and four groups were ultratranslucent monolithic zirconia ceramic materials (Prettau, Aidite, Shofu, Dima) (Table 1). All specimens were subjected to one cycle of glazing using glaze paste (FLUO; IPS Ivoclar Glaze Paste, Ivoclar Vivadent, Schaan, Liechtenstein) at a temperature recommended by the manufacturer. Resin discs measuring 9 mm in diameter and 1 mm in thickness with shade A1 were fabricated to serve as tooth colored substructures (NextDent C&B MFH, 3D Systems, Vertex Dental B.V., Soesterberg, Netherlands). Specimens were kept in separate containers until testing.

Try-in pastes in neutral, light, and warm hues were employed to mimic the impact of cement on the color of the ceramic specimen (Variolink Esthetic try-in paste; Ivoclar Vivadent, Schaan, Liechtenstein). Before application of each try-in paste, each specimen was cleaned in tap water and dried with gauze and

**Table 1.** Materials utilised in the study

| Material | Material Type | Trade Name | Manufacturer | Chemical Composition |
|---|---|---|---|---|
| e.max | Pressable lithium disilicate | IPS e.max Press | Ivoclar Vivadent, Schaan, Liechtenstein | $Li_2Si_2O_5$ 70%, $ZrO_2$ 4% |
| Aidite | Ultra-translucent multilayer monolithic zirconia 5-6Y-PSZ | Aidite 3D Pro Zir | Aidite, Bracon Digital Dental Products, UK | $ZrO_2$ 90 - 95%, $Y_2O_3$ 4 - 10%, $Al_2O_3$ < 0.5%, other oxides < 0.5% |
| Prettau | Ultra-translucent multilayer monolithic zirconia 5Y-PSZ | Prettau 4 Anterior Dispersive | Zirkonzahn GmbH, South-Tyrol, Gais, Italy | $ZrO_2$ 90%, $Y_2O_3$ < 12%, $SiO_2$ < 0.02%, $Al_2O_3$ < 1%, $Fe_2O_3$ 0.01% |
| Shofu | Super-translucent multilayer monolithic 3YTPZ-5YPSZ | Shofu Disk Zr Lucent Supra | Shofu Dental GmbH, Tosoh, Japan | $ZrO_2$ 94 - 96%, $Y_2O_3$ 3 - 5%, $Al_2O_3$ < 0.5%, other oxides < 0.5% |
| Dima | High translucent multilayer monolithic zirconia 3Y-TPZ | Dima Mill Zirconia HTE | Kulzer GmbH, Hanau, Germany | $ZrO_2$ 96%, $Y_2O_3$ 3%, $Al_2O_3$ < 0.5%, other oxides < 0.5% |
| Variolink | Resin try-in paste | Variolink Esthetic try-in paste | Ivoclar Vivadent, Schaan, Liechtenstein | Glycerine, mineral fillers, dyes |

air. A calibrated mold was used to accommodate the resin disk substrates over which the specimens were luted. To standardize the try-in cement thickness, the mold had a cylindrical depth of 1.6 mm (1-mm resin disk thickness + 0.1-mm cement thickness + 0.5-mm specimen thickness) (Fig. 1). First, the resin disks were placed within the mold. Next, a drop of try-in paste was applied on the resin disk (Fig. 2A). The specimens were placed over the try-in paste held from their glazed surfaces with an adhesive tip of a microbrush, and they were gently pressed (Fig. 2B). To seat the specimen within the mold borders and remove extra try-in paste material, a glass plate was placed over the mold surface.

Each material group (n = 8) underwent color measurement at baseline before application of the cement, and it was then measured using three cement shades. After taking the color readings for the first try-in paste, each specimen was first washed in running water and then placed in an ultrasonic cleaning bath according to the manufacturer's instructions to remove the try-in paste. After washing out the first cement, the process was repeated for the other two shades of cement.

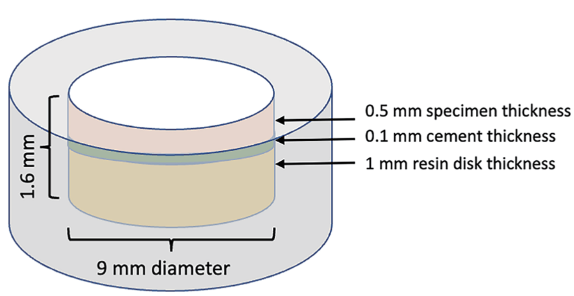


**Fig. 1.** Schematic diagram of the calibrated mold used to accommodate the resin disk substrates over which the specimens were luted.


**Fig. 2.** (A) Drop of try-in paste applied on the resin disk within the mold. (B) Specimen placed over the try-in paste drop. (C) Glass plate pressed over the surface of the mold to seat the specimen within the borders of the mold.

For color evaluation, the L*a*b* values for each item were measured using a spectrophotometer (LabScan-XE®, Hunter-Lab, Sunset Hills Road, Reston, VA, USA) against a black backdrop and a white background at three different angles. For each specimen, the readings were taken three times. The following equations were used to compute the translucency parameter (TP) and delta E value (E) using the L*a*b* values:

$$\Delta E = [(L^*_2 - L^*_1)^2 + (a^*_2 - a^*_1)^2 + (b^*_2 - b^*_1)^2]^{1/2}$$

where subscripts 1 and 2 indicate values at baseline and after cement application, respectively.

$$TP = [(L^*_b - L^*_w)^2 + (a^*_b - a^*_w)^2 + (b^*_b - b^*_w)^2]^{1/2}$$

where a* denotes the green (-a) and red (+a) axes, b* denotes the blue (-b) and yellow (+b) axes, and b and w denote the black and white backdrops, respectively.

The ΔE and TP values were calculated for each sample before (baseline) and after the application of try-in pastes.

Statistical analysis was performed using SPSS (version 26.0, IBM Inc., Armonk, NY, USA). The spectrophotometer-derived quantitative outcome variables L*, a*, and b* color coordinates were described using descriptive statistics (mean and standard deviation). The statistical analysis compared the mean ΔE and TP values computed from the aforementioned formulas with confidence intervals of 95% for all samples to identify differences among the material groups within each shade of cement and to identify differences among various shades of cements within the same material. One-way analysis of variance (ANOVA) and Tukey's post hoc tests for multiple comparisons were used. The significance threshold was set to $\alpha < 0.05$.

## RESULTS

Table 2 provides descriptive data for the mean and standard deviation of L* values obtained from the spectrophotometer reading for the five tested materials. All the materials tested demonstrated significant decreases in their L* values for all three shades ($P < .05$). Surprisingly, the light shade, which was expected to increase the lightness of the restoration, reduced the L* parameter relative to baseline ($P < .05$). However, the light shade resulted in higher L* values than the other two shades. Even though all of the materials were constructed using shade A1, there were significant variations in the lightness of the materials tested at baseline before exposure, with Prettau zirconia demonstrating the lowest lightness value among all the materials tested with all three shades.

Table 3 displays the mean and standard deviation values of a* before and after cementation with the three shades of cements. All the tested materials demonstrated significant changes ($P < .05$) in the a* color coordinate leaning toward the green zone of the red-green axis after cementation, except for Dima zirconia ($P = .865$). All the groups at different shades of cements were interestingly negative. However, e.max was less green and redder than the other materials at baseline. The most noticeable shift in the a* value from baseline was seen in the e.max group, with the light shade moving toward the green zone of the red-green axis.

**Table 2.** Mean and standard deviation (SD) values of the L* color coordinate obtained from the spectrophotometer for the five test materials before (baseline) and after try-in cementation

| Cement Shade | e.max | Aidite | Prettau | Shofu | Dima | **P*-value |
|---|---|---|---|---|---|---|
| Baseline | 67.60 (0.39) | 68.23 (0.50) | 63.81 (0.49) | 67.00 (0.78) | 67.77 (0.76) | < .000 |
| Neutral | 62.49 (1.27) | 62.42 (0.55) | 58.62 (0.82) | 61.59 (1.42) | 63.47 (1.50) | < .000 |
| Light | 64.18 (1.17) | 63.04 (0.76) | 59.81 (0.72) | 61.85 (0.84) | 62.82 (1.68) | < .000 |
| Warm | 62.39 (1.70) | 61.66 (1.16) | 57.97 (0.70) | 60.94 (0.72) | 62.14 (0.58) | < .000 |
| ***P*-value | < .000 | < .000 | < .000 | < .000 | < .000 | |

**P* value was significant at $P < .05$ for comparisons between different materials within each shade.
** *P* value was significant at $P < .05$ for comparisons between different shades within each material.

**Table 3.** Mean and standard-deviation (SD) values of the a* color coordinate obtained from the spectrophotometer for the five test materials before (baseline) and after try-in cementation

| Cement Shade | e.max | Aidite | Prettau | Shofu | Dima | *P-value |
|---|---|---|---|---|---|---|
| Baseline | -1.53 (0.07) | -2.56 (0.15) | -2.71 (0.11) | -2.61 (0.89) | -2.76 (0.14) | < .001 |
| Neutral | -1.95 (0.11) | -2.54 (0.05) | -2.58 (0.06) | -2.53 (0.09) | -2.77 (0.08) | < .001 |
| Light | -2.15 (0.26) | -2.73 (0.11) | -2.71 (0.10) | -2.72 (0.13) | -2.61 (0.28) | < .001 |
| Warm | -1.99 (0.12) | -2.71 (0.18) | -2.79 (0.14) | -2.64 (0.81) | -2.71 (0.11) | < .001 |
| **P-value | < .000 | < .01 | < .01 | < .01 | > .05 | |

*$P$ value was considered significant at $P < .05$ for comparisons between different materials within each shade.
**$P$ value was considered significant at $P < .05$ for comparisons between different shades within each material.

**Table 4.** Mean and standard-deviation (SD) values of the b* color coordinate obtained from the spectrophotometer for the five test materials before (baseline) and after try-in cementation

| Cement Shade | e.max | Aidite | Prettau | Shofu | Dima | *P-value |
|---|---|---|---|---|---|---|
| Baseline | 3.04 (0.13) | 2.62 (0.43) | 2.15 (0.42) | 1.87 (0.58) | 2.14 (0.26) | < .001 |
| Neutral | 2.18 (0.22) | 2.01 (0.38) | 1.95 (0.39) | 1.02 (0.33) | 1.70 (0.56) | < .001 |
| Light | 1.71 (0.51) | 1.69 (0.61) | 2.09 (0.49) | 1.11 (0.73) | 1.44 (0.11) | < .05 |
| Warm | 3.09 (0.51) | 1.68 (0.36) | 1.97 (0.35) | 1.41 (0.54) | 1.49 (0.12) | < .001 |
| **P-value | < .001 | < .001 | > .05 | < .05 | < .001 | |

*$P$ value was considered significant at $P < .05$ for comparisons between different materials within each shade.
**$P$ value was considered significant at $P < .05$ for comparisons between different shades within each material.

In Table 4, the mean and standard deviation values of the b* color coordinate are displayed. All materials, except for the Prettau zirconia ($P = .747$), demonstrated significant changes ($P < .05$) in the b* value following cementation with the three cement shades. Despite all of the materials being constructed using shade A1, there were significant differences ($P < .05$) in the b* parameter of the materials tested at baseline, with e.max being the yellowest (3.04) and Shofu being the bluest (1.87). The biggest b* value drop was recorded in the e.max with the light shade moving considerably toward the blue zone of the yellow-blue axis. All the tested materials turned bluer than the baseline after cementation, except for Prettau.

Figure 3 displays the calculated TP of the five test materials at baseline and after cementation with three shades of try-in pastes. The translucency of the materials was significantly different at baseline, with the highest TP value recorded for Prettau (1.59) and the lowest for Shofu (0.36). The TP values of Shofu and Dima ceramics were lower after cementation, but these decreased TP values were not statistically significant ($P > .05$). For e.max, translucency decreased after cementation with neutral and warm shades and significantly increased after cementation with light shades. Aidite and Prettau demonstrated slight increases in their translucency with the neutral and warm shades and decreases in their TPs with the light shade; however, these variations were not statistically significant ($P > .05$).

Figure 4 demonstrates a significant change in color ($\Delta E$) observed in all tested materials after cementation, with $\Delta E$ values exceeding 3.3 ($P < .05$). The $\Delta E$ value was the highest in Aidite zirconia when using the warm shade (6.83), and the smallest color change was seen in the e.max when using the light shade (3.82).

## DISCUSSION

The recently launched ultratranslucent multilayer monolithic zirconia ceramics for veneer restorations were compared with the widely used aesthetic lithium disilicate ceramic material in the present study to assess the effects of cement shade on color and translucency. The L*a*b* Commission Internationale

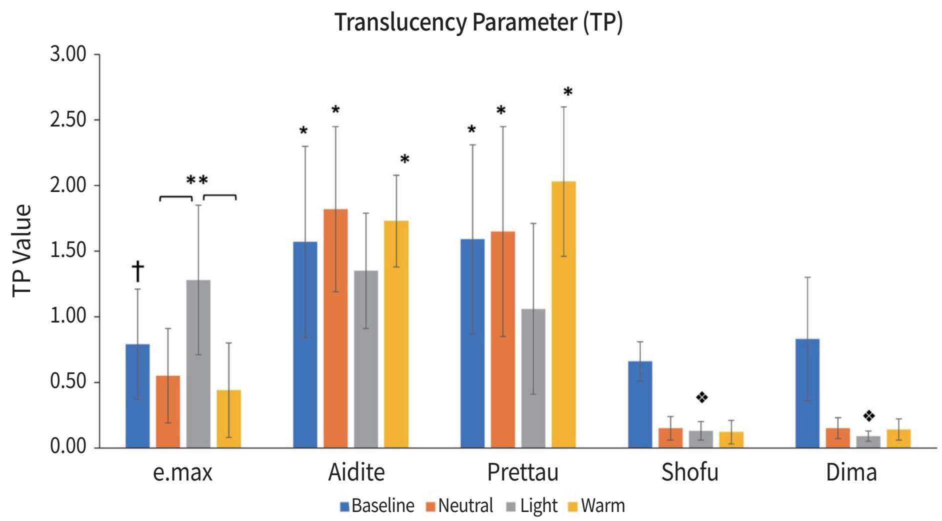


**Fig. 3.** Translucency parameters (TP) of the five test materials at baseline and after cementation with three shades of try-in pastes.
* Indicates a statistically significant difference ($P < 0.5$) in the TP values of Aidite and Prattau relative to other materials with the same cement shade.
† Indicates a statistically significant difference ($P < 0.5$) in TP values of e.max relative to other materials with the baseline shade.
❖ Indicates a statistically significant difference ($P < 0.5$) in the TP values of Shofu and Dima relative to other materials with the light shade.
** Indicates a statistically significant difference ($P < 0.5$) in TP values with the shades of the e.max material.

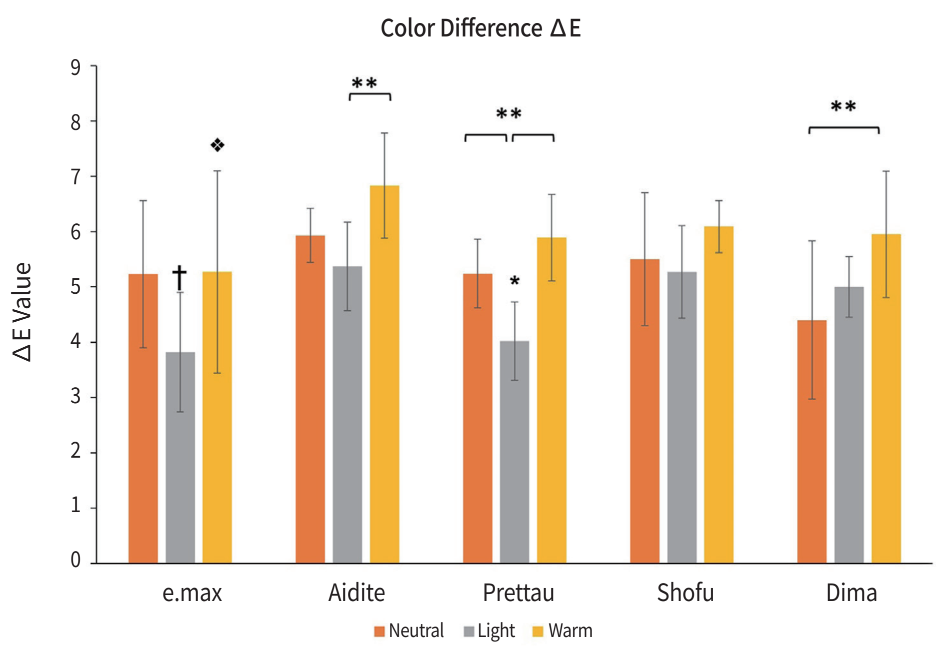


**Fig. 4.** Color differences (ΔE) between baseline and the three shades of try-in paste cements for the five tested materials.
* Indicates a statistically significant difference ($P < 0.5$) in the ΔE values of Prattau relative to other materials with the light shade.
† Indicates a statistically significant difference ($P < 0.5$) in ΔE values of e.max relative to other materials with the light shade.
❖ Indicates a statistically significant difference ($P < 0.5$) in the ΔE values of e.max relative to other materials with the warm shade.
** Indicates a statistically significant difference ($P < 0.5$) in ΔE values with the shades of the same material.

de l'Eclairage (CIE) numeric color system, in which the L*a*b* coordinates were derived from a spectrophotometer, was used to evaluate the aforementioned optical qualities. In the realm of color analysis of dental materials, the use of a spectrophotometer has received widespread acceptance as an effective technique to record the CIE L*a*b* color coordinates.[3,4,9,11-13] Using the same color measurement tool as the present study, the recent study of Miura *et al*.[8] on the influences of abutment tooth and luting agent colors on the final color of high-translucent zirconia crowns presented color variations among various cement shades, with ΔE values ranging from 1.39 to 4.27 depending on the evaluated tooth portion and the shade of crown and luting cement used. The results of this study demonstrated a similar outcome in which the shade of the luting cement significantly altered the color of the tested ceramic materials. However, the ΔE values of the present investigation were higher, ranging from 3.82 to 6.83, and were all at a level above the threshold at which the clinical perception of color change occurs (> 3.3).[14,15] In this investigation, specimens with a uniform thickness of 0.5 mm were employed, while the prior study involved specimens with varying thicknesses ranging from 0.8 mm to 2 mm, which could be the cause of the variance in the range of E values between the two studies.[8] Bayindir *et al*.[11] illustrated earlier that the effect of cement shade was linked to the ceramic thickness and that the highest ΔE values (8.05) were associated with samples having 0.5 mm thicknesses, which was the thickness used in this study. The translucency of the final restoration was observed to be impacted by the cement color, and the mean TP values of the specimens cemented with transparent cement at all thicknesses were higher than those of the specimens cemented with opaque cement,[11] according to the authors. This conclusion conflicted with the findings of this investigation, which showed that there were no appreciable changes in the TP values within any material when using various shades of cement. Such conflicting results could be attributed to the fact that the study performed by Bayindir *et al*.[11] involved one type of monolithic zirconia ceramic material, Katana High Translucent, while the present study involved five materials other than Katana. The TP values in this study, however, differed significantly among the different materials within each shade. This observation highlighted the fact that the TP was material dependent, suggesting that it was an inherent feature of the material and was significantly dependent on light scattering.[16] A ceramic could appear opaque if the majority of light traveling through it was strongly dispersed and diffusely reflected. The substance would look translucent[16] if only a small portion of the light was dispersed and most of the light was diffusely transmitted. The number of crystals present in the matrix, their chemical composition, and the particle size relative to the wavelength of the received light all affected how much light was absorbed, reflected, and transmitted.[16] Various crystal volumes and the material refractive indices could be connected to variations in translucency among the materials recently being studied. Light scattering was reduced by a crystalline content that was lower and by refractive indices that were close to those of the matrix.[16]

According to an analysis of the monolithic zirconia materials tested, two materials, Dima and Shofu, demonstrated the lowest TP values at baseline and after cementation. Both materials were categorized as high translucent and indicated for veneer restorations, but they were classified as tetragonal zirconia polycrystals (3Y-TZP) and tetragonal zirconia-polycrystals comprising 3 mol% yttria (3Y-TZP) and partially stabilized zirconia containing 5 mol% yttria (5Y-PSZ)[17] based on their inherent properties in which Dima was a polychromic multilayer with a uniform composition of tetragonal zirconia-polycrystals (3Y-TZP) comprising 3 mol% yttria, while Shofu was a polychromic multilayer and hybrid composition of two phases: tetragonal zirconia-polycrystals comprising 3 mol% yttria (3Y-TZP) in one area and partially stabilized zirconia containing 5 mol% yttria (5Y-PSZ) in another area. Such alterations in the composition of conventional tetragonal zirconia polycrystals (3Y-TZP) resulted in an increase in their translucency.[17] Because their existence caused volumes of varying refractive indices and induced light scattering on the surface, resulting in diminished translucency, the remaining holes and impurities were reduced to the absolute minimum during processing due to the altered crystal structure.[18] Because the yttria content was increased from 3 mol% to between 5 and 6 mol% Y-PSZ, additional cubic polycrystals that were voluminous and had a highly isotropic cubic phase that allowed light transmission were produced, improving translucent monolithic zirconia restorations, while alumina was the most common impurity that was reduced to increase translucency.[18] According to Carrabba *et al.*,[19] 5Y-PSZ exhibited a translucency value that was between that of 3Y-TZP and lithium disilicate glass-ceramic.[19] However, this finding was not consistent with the present investigation, where Aidite and Prettau demonstrated the highest TP values among all materials tested, including e.max. The present results were in line with the earlier findings of Baldissara *et al.*,[20] who reported higher translucency for cubic zirconia than that of lithium disilicate glass-ceramic.[20] The increased translucency of these PSZ was related to the increased content of yttria >5 mol%, creating a highly transparent phase with increased amounts of nonbirefringent cubic crystals.[2] The optical physics of zirconia were enhanced by the cubic crystal shape and grain size. Since the crystal of the cubic system was optically isotropic, the refractive index was constant across the crystal lattice. Additionally, the cubic polymorph of zirconia had a reduced grain-boundary area per unit volume due to its grain size being outside of the visible red spectrum. The optical characteristics indicated above would result in less light scattering at the grain boundary, increasing the quantity of light transmittance.[21]

The TP values tended to decrease after cementation, but the decrease was not statistically significant. The absence of statistical significance was because of the high standard deviation values within the same material. This extreme variation in TP values between specimens of the same material could be due to the fabrication method of the specimens. To guarantee that the specimens covered the entire polychromatic gradient spanning from enamel to dentine colors, the 98 mm multilayer monolithic zirconia block was longitudinally cut along its entire thickness. The color measurements were then taken at three different points, and the mean was calculated. It is possible that the specimens could have been taken from the same side in the block to standardize shade differences in multilayered monolithic zirconia, such as taking from the layer of the enamel shade side of the blocks for all materials, to replicate the natural teeth color gradient running from enamel to dentine. This action would have prevented variations in TP values within the same material group from affecting the statistical significance value.[18]

All of the materials showed considerable color changes as a result of the three try-in cement hues (neutral, light, and warm) used in this investigation. By replicating the color effect created by the fully polymerized resin luting agent after light activation, a try-in paste helped with crown color prediction.[8] According to their manufacturer, Variolink Esthetic shades were named according to their effect on the finished restoration rather than their effect on the color of the resin paste. Warm shades darkened the restoration; light shades lightened the restoration, and neutral shades had no shade effect, as they were considered translucent. Surprisingly, the neutral shade caused a significant alteration in the final shades of all the tested materials, with $\Delta E > 4$. In fact, the color changes induced by the neutral shade were higher than those induced by the light shade, especially for the e.max and Prettau materials. This finding was similar to the results of Comba *et al.*,[10] who demonstrated a significant color change ($\Delta E$ 5.5) in lithium disilicate samples when using translucent shade from Rely X Veneer cement.[10] However, the authors did not find significant color variation in the zirconia material tested when using the translucent shade, unlike the results of this study. This inconsistency could be related to the different zirconia types used, such as Katana 3Y-TZP, and the different cement types used, such as Rely X,[10] while this study involved Variolink Esthetic. Factors such as the type of filler, resin matrix, photoinitiator, polymerization, and degree of conversion affect the color of resin cements.[6] As a result, comparable colors but different cement types could have a varied effect on the color of the final restoration.[22,23] Several scholars have reported higher $\Delta E$ values than the Rely X Veneer groups when using Variolink Esthetic.[6,24] The authors attributed these high values to the presence of a different photoinitiator (Ivocerin) in Variolink Esthetic cement, which when exposed to light, reacted with monomers to promote polymerization. This phenomenon resulted in increased polymerization, improved reactivity to the curing light and increased depth of cure.[6,25] The use of only one type of luting cement was considered one of the limitations in this study. In terms of filler content or activation mode,[26] the entity of color variation could be connected to the chemical composition of the cement material itself. When working with restorations that require high aesthetic standards, choosing the cement color correctly was crucial, and clinicians must be aware that a poor choice of cement color could damage the restoration final aesthetic outcome.[26] Another limitation included the lack of clinical simulation with actual teeth as substrates and artificial aging. Earlier studies showed that zirconia could undergo changes in translucency due to aging and could be related to the transformation from the tetragonal to monoclinic phase.[10,27] Furthermore, the use of resin substrates, that behave differently in terms of their optical properties relative to natural teeth[8,28] was another limitation. It would have been beneficial if more shades of resin substructure were selected to further expand the results into clinical application. Additionally, it was of clinical significance if the investigators performed visual comparisons by taking some photos for samples before and after cementation since $\Delta E$ values obtained were above the clinical perception level of the human eye. Overall, the present findings suggested that dental practitioners should carefully consider the choice of cement shade when cementing dental restorations to achieve optimal aesthetic outcomes. To fully assess the crucial factors that could affect the ultimate color of recently introduced ultratranslucent zirconia ceramics, additional studies could be required to validate the obtained results, possibly enhancing the simulation of the clinical situation. Future research should consider providing clinical guidelines for optimum material-cement combinations in terms of optimal color outcome.

## CONCLUSION

Within the limitations of this research, it could be concluded that the shade of luting cement significantly altered the final color of the ceramic veneer material to a level above the threshold at which the clinical perception of color change occurred (> 3.3), while the translucency parameter was not significantly influenced by the cement shade. The translucency of the novel ultratranslucent multilayer monolithic zirconia ceramics Aidite and Prettau was higher than that of the lithium disilicate e.max material. These findings highlighted the importance of the cement shade selection step in the cementation procedures of new zirconia veneers and suggested that dental practitioners should carefully consider the choice of cement shade to achieve optimal color matching outcomes.

## ACKNOWLEDGMENTS

The authors would like to thank the College of Dentistry Research Center at King Saud University for facilitating the project and providing physical laboratory to run the experiment.

## REFERENCES

1. Gresnigt MMM, Cune MS, Jansen K, van der Made SAM, Özcan M. Randomized clinical trial on indirect resin composite and ceramic laminate veneers: Up to 10-year findings. J Dent 2019;86:102-9.
2. Zhang Y, Lawn BR. Novel Zirconia Materials in Dentistry. J Dent Res 2018;97:140-7.
3. Nogueira AD, Della Bona A. The effect of a coupling medium on color and translucency of CAD-CAM ceramics. J Dent 2013;41 Suppl 3:e18-23.
4. Alrabeah G, Shabib S, Almomen R, Alhedeithi N, Alotaibi S, Habib SR. Effect of home bleaching on the optical properties and surface roughness of novel aesthetic dental ceramics. Coatings 2023;13:330.
5. El-Sayed SM, Basheer RR, Bahgat SF. Color stability and fracture resistance of laminate veneers using different restorative materials and techniques. Egypt Dent J 2016;62:1-15.
6. Adel E, Al-Zordk W, Hasouna M, Elsherbini A, Sakrana AA. Color stability and translucency of ceramic laminate veneer restoration for diastema closure: Effect of resin cement containing different photoinitiators. 2022. preprint.
7. Tabatabaian F, Khaledi Z, Namdari M. Effect of ceramic thickness and cement type on the color match of high-translucency monolithic zirconia restorations. Int J Prosthodont 2021;34:334-40.

8. Miura S, Tsukada S, Fujita T, Isogai T, Teshigawara D, Saito-Murakami K, Asami K, Fujisawa M. Effects of abutment tooth and luting agent colors on final color of high-translucent zirconia crowns. J Prosthodont Res 2022;66:243-9.
9. Ayash G, Osman E, Segaan L, Rayyan M, Joukhadar C. Influence of resin cement shade on the color and translucency of zirconia crowns. J Clin Exp Dent 2020;12:e257-63.
10. Comba A, Paolone G, Baldi A, Vichi A, Goracci C, Bertozzi G, Scotti N. Effects of substrate and cement shade on the translucency and color of CAD-CAM lithium-disilicate and zirconia ceramic materials. Polymers (Basel) 2022;14:1778.
11. Bayindir F, Koseoglu M. The effect of restoration thickness and resin cement shade on the color and translucency of a high-translucency monolithic zirconia. J Prosthet Dent 2020;123:149-54.
12. Alrabeah G, Habib SR, Alamro NM, Alzaaqi MA. Evaluation of the effect of electronic cigarette devices/vape on the color of dental ceramics: an in vitro investigation. Materials (Basel) 2023;16:3977.
13. Hardan L, Bourgi R, Cuevas-Suárez CE, Lukomska-Szymanska M, Monjarás-Ávila AJ, Zarow M, Jakubowicz N, Jorquera G, Ashi T, Mancino D, Kharouf N, Haikel Y. Novel trends in dental color match using different shade selection methods: a systematic review and meta-analysis. Materials (Basel) 2022;15:468.
14. Funt BV, Roshan E. Metamer mismatching underlies color difference sensitivity. J Vis 2021;21:11.
15. Lindsey DT, Wee AG. Perceptibility and acceptability of CIELAB color differences in computer-simulated teeth. J Dent 2007;35:593-9.
16. Heffernan MJ, Aquilino SA, Diaz-Arnold AM, Haselton DR, Stanford CM, Vargas MA. Relative translucency of six all-ceramic systems. Part I: core materials. J Prosthet Dent 2002;88:4-9.
17. Ban S. Classification and properties of dental zirconia as implant fixtures and superstructures. Materials (Basel) 2021;14:4879.
18. Ziyad TA, Abu-Naba'a LA, Almohammed SN. Optical properties of CAD-CAM monolithic systems compared: three multi-layered zirconia and one lithium disilicate system. Heliyon 2021;7:e08151.
19. Carrabba M, Keeling AJ, Aziz A, Vichi A, Fabian Fonzar R, Wood D, Ferrari M. Translucent zirconia in the ceramic scenario for monolithic restorations: A flexural strength and translucency comparison test. J Dent 2017;60:70-6.
20. Baldissara P, Wandscher VF, Marchionatti AME, Parisi C, Monaco C, Ciocca L. Translucency of IPS e.max and cubic zirconia monolithic crowns. J Prosthet Dent 2018;120:269-75.
21. Kim HK. Optical and mechanical properties of highly translucent dental zirconia. Materials (Basel) 2020;13:3395.
22. Czigola A, Abram E, Kovacs ZI, Marton K, Hermann P, Borbely J. Effects of substrate, ceramic thickness, translucency, and cement shade on the color of CAD-CAM lithium-disilicate crowns. J Esthet Restor Dent 2019;31:457-64.
23. Carrabba M, Vichi A, Tozzi G, Louca C, Ferrari M. Cement opacity and color as influencing factors on the final shade of metal-free ceramic restorations. J Esthet Restor Dent 2022;34:423-9.
24. Espíndola-Castro LF, Brito OFF, Araújo LGA, Santos ILA, Monteiro GQM. In vitro evaluation of physical and mechanical properties of light-curing resin cement: a comparative study. Eur J Dent 2020;14:152-6.
25. Ilie N. Impact of light transmittance mode on polymerisation kinetics in bulk-fill resin-based composites. J Dent 2017;63:51-9.
26. Mazzitelli C, Paolone G, Sabbagh J, Scotti N, Vichi A. Color stability of resin cements after water aging. Polymers (Basel) 2023;15:655.
27. Kilinc H, Sanal FA. Effect of sintering and aging processes on the mechanical and optical properties of translucent zirconia. J Prosthet Dent 2021;126:129.e1-129.e7.
28. Li S, Wang Y, Tao Y, Liu Y. Effects of surface treatments and abutment shades on the final color of high-translucency self-glazed zirconia crowns. J Prosthet Dent 2021;126:795.e1-795.e8.